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Bacterial population of Rhizospheres and non-Rhizospheres of the mangrove species *Rhizophora mucronata* from 0 to 10 cm deep

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***Abstract*—** *The interaction of plants and microorganisms in the rhizospheres and non-rhizospheres of plants is well studied and mastered in the terrestrial environment. In general, given the rhizosphere effect exclusively defining the effectiveness of root exudates to promote multiplication, development and microbial growth in the rhizosphere zones, studies unanimously tend to report that the microbial biomass is rather high in the rhizosphere than in the non-rhizosphere. However, the trend may change in the marine environment. This study was conducted in both the rhizosphere and non-rhizosphere of the mangrove species Rhizophora mucronata at different depths ranging from 0-10 cm, to assess the bacterial community in the rhizosphere and non-rhizosphere and to also address the profile of bacterial community changes. The result showed no difference regarding the bacterial abundance in the rhizosphere and in the non-rhizosphere. However, the abundance of bacteria at 0-5 cm depth was significantly higher in rhizosphere and non-rhizosphere. This could be attributed to the large amount of nutrients available in the surface layer. The unequal distribution of nutrients in the rhizosphere and non-rhizosphere of the mangrove species Rhizophora mucronata could be the consequences of mineralization, immobilization of nutrients in the soil and especially root exudation. The general results of this study can be summarized by showing that if the abundance of bacteria in the rhizosphere zones of terrestrial plants is often high, the trend may be different in aquatic plants, more particularly mangroves, which constitute a separate ecosystem.*

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I. INTRODUCTION

The interaction of plants and microorganisms in the rhizospheres and non-rhizospheres of terrestrial plants is well studied and mastered in the terrestrial environment. Most plants host diverse communities of microorganisms such as bacteria, fungi, archaea and protists (Ankati and Podile 2019). Various microorganisms can be encountered in the internal parts of the leaves, stems, roots, fruits and flowers, they are called endophyte microorganisms. Others can be encountered on the surfaces of the roots, these are the rhizoplanes, while others parts live on the aerial parts such as the leaves, fruits and flowers known as the phyllosphere. There are others microorganisms living in the vicinity of the roots known as the rhizosphere.

The rhizosphere is defined as the narrow volume of soil near root surfaces, with chemical properties directly affected by root exudates (O'Brien et al. 2018). In this environment heterotrophic microbes, including bacteria, fungi, protozoa, archaea and nematodes are attracted by organic compounds released by plants (Meng and Chi 2017). Chemotaxis, electronic signals characterized by electrical root surface potentials are among the causes of the attraction of various microbial species to root surfaces (Miura et al. 2019). Thus, cross-communication between plant roots and the associated microbiome is developed, and is necessary for the selective microbial colonization of roots (Huang et al. 2014). Studies of the microbial community of the rhizosphere compared to that of non-rhizosphere on terrestrial plants have shown great variation. This may be related to the fact that rhizosphere microorganisms benefit not only from organic compounds contained in the soil but also those released by plant roots. On the other hand, non-rhizosphere microbial communities obtain only mineral contents that make up the soil. On the aquatic and marine environment such as mangroves, studies comparing rhizosphere and non-rhizosphere community bacteria are rare and divergent.

Mangroves are particular plants developed in a complex ecotone between terrestrial and marine environments (Alzubaidy et al. 2016). The mangrove ecosystem is of great ecological importance not only for the various marine species that use this area as a refuge and feeding place, but also for the multitude of microorganisms that it harbors (Rigonato et al. 2018; Thatoi et al. 2012). This environment is subject to constant variations in water level, salinity, temperature and oxygen content, making these sites a reservoir of microbial species adapted to these changing conditions (Wanapaisan et al. 2018). The microbial diversity and abundance of the rhizosphere and non-rhizosphere in mangrove ecosystems may well be distinguishable from those on the terrestrial, due to these changes in living conditions that remain poorly documented.

This study is interested in establishing the bacterial community of the rhizosphere and non-rhizosphere of a species of mangroves (*Rhizophora mucronata*) in Ouroveni in the Mbadjini-East region, Grande-Comoros. Therefore, rhizosphere and non-rhizosphere sediment samples are collected at a depth of 0-10cm. The aim of this study was to (i) compare the bacterial population of the rhizosphere of *R mucronata* with that of non-rhizosphere; (ii) identify the different nutrients present in the two media and (iii) establish a correlation between the different factors influencing bacterial diversity and dispersion in these two areas.

II. MATERIALS AND METHODS

1- Collection of samples

Samples of rhizosphere (R) and non-rhizosphere (NR) mangroves were collected in the coastal area of Ouroveni in Mbadjini-Est, Grande-Comoros (longitude: 11°54'45 S, latitude: 43°41'08 E and altitude: 0m). Three places along the closure of the intertidal zone to deep in the mangrove forest were chosen for the collection of rhizosphere sediments noted R1, R2 and R3 respectively. Sediment adhering to mangrove roots was collected as rhizosphere sediment, while non-rhizosphere sediment was collected away from plants and roots in particular. Polyvinyl chloride (PVC) tubes of 4.2 cm in diameter and 50 cm of length were used to collect sediment to a depth of 10 cm. Different depths are denoted as follows: Ni-1 (0-5 cm) and Ni-2 (5-10 cm), (N can be R or NR and i varies from 1 to 3). The stones or roots were removed and then the samples were transported to the laboratory of Animal and cellular biology at the university of Comoros to be preparing and sent to the environmental microbiology laboratory at Shantou University, Guangdong in China, for further analysis. The samples were divided into two groups, the first was stored at -4°C for the determination of the physical and chemical characteristics of the sediments and the other group used for the DNA analysis was stored at -20° C before DNA extraction.

2- Determination of physical and chemical properties

The temperature, pH and the value of the oxidation-reduction potential (ORP) at different depths, from the surface layer (0-5 cm) to the lower layer (5-10 cm) were measured respectively by using a hand-held thermometer, pH meter and ORP meter. Soil sediments were air-dried, crushed and sieved to 2 mm. For the determination of other characteristics, approximately 0.5 g of crushed sediment

was added in an Erlenmeyer flask, and digested by using the aqua-regia extraction method in three replicates (Victorio et al. 2020). Indeed, 10 mL of HCl/HNO3:/O4 (3:1) was added in the flask and digested at 180-200°C on a hot plate. The digested solution was diluted to 50 mL using deionized water and filtered. Fe, Mn, Zn, Mg, K and Ca were analyzed by inductively coupled plasma optical emission spectrometry (ICPOES). The standard concentration of 1000 mg/L was prepared for the calibration curves. Total nitrogen (TN), nitrate and nitrite were determined using the Kjeldahl method as described in (Willis et al. 1996). Phosphorus contents were analyzed using a double digestion with $H_2SO4/HCIO4$. Carbon and sulfur were determined by dry combustion using a high temperature induction furnace as described in (Lavkulich et al. 1970).

3- DNA extraction and amplification

Total genomic DNA of the different sample was extracted using an Ultra-Clean Microbial DNA Isolation Kit (MoBio Laboratories, Carlsbad, CA, USA). Polymerase Chain Reaction (PCR) amplification of the 16S rRNA genes from the V3-V4 region of each sample was conducted by using the universal primers, 338F (5'-ACTCCTACGGGAGGCAGCAG-3') and 806R (5'-GGACTACHVGGGTWTCTAAT-3') as was described in (Huang et al. 2014). The extracted DNA was sent to Sangon Biotec Institute (SBI) platform at Shanghai, China, to be sequenced. DNA concentrations and purity were measured using a NanoDrop 2000 spectrophotometer (Thermo Fisher Scientific, USA).

Computational analysis

The de-duplication and filter-qualification of the raw fastq files, sequences classification, annotation and beta diversity distance calculation were performed by using Quantitative Insights Into Microbial Ecology (QIIME Version 1.9). UPARSE software (version 7.0.1001) was used to group the filtered sequences OTUs clustered with a 97% similarity cutoff. At 97% of confidence threshold, the taxonomy of each 16S rRNA gene sequence was analyzed using 16S rRNA database and the RDP Classifier (version 2.11). Different functional genes composition of bacterial community was determined by using PICRUST.

Statistical Analysis

Data were subjected to statistical analysis of variance (ANOVA) in SPSS (20) software. Differences between means and multiples stepwise were performed using the appropriate post-hoc with a 95% confidence level. ANOSIM was used to evaluate similarities among different experimental group. The Shannon index was calculated to describe α diversity and the richness of microbiota. Different graphs were performed by using SigmaPlot and Origin pro.

III. RESULTS

1- Physical and chemical characteristics of rhizospheres and non-rhizosphere

The in situ environmental properties of the rhizosphere and non-rhizosphere are presented in the following Table 1. Although no significant difference was noted, the pH value in the rhizosphere (R) was slightly low compared to that of the non-rhizosphere (NR).

1.1- Concentration of ORP, nitrate and nitrite

The ORP was determined in the different experimental groups and in the different depth zones. What was interesting is that in the deep zone of non-rhizosphere 2 (NR2-2) and rhizosphere 3 (R3-2), the ORP was negative, indicating a reduction phenomenon and positive in the layer upper, indicating an oxidation process. By comparison of ORP in rhizosphere and non-rhizosphere, no significant difference was found.

Compared to the non-rhizosphere, the nitrate (NO3-) concentration in the rhizosphere was significantly ($p <$ 00.5) considerable. Considering the non-rhizosphere, the surface nitrate concentration (NR1-1, NR2-1 and NR3-1) was large compared to that of the underlying sampling area (NR1-2, NR2-2 and NR3 -2). Unlike in the non-rhizosphere, in the rhizosphere the situation was totally different. In the deep sampling area (R1-2, R2-2 and R3-2), the nitrate concentration was slightly higher than that recorded in the surface levels.

1.2. Concentration of ammoniacal nitrogen, calcium, potassium and phosphorus

The concentration of ammoniacal nitrogen (NH3-N) was considerable in the rhizosphere compared to that of the non-rhizosphere, especially in R2-1. However, taking into consideration the “depth” factor, no difference was observed in the rhizosphere and non-rhizosphere samples. The carbon concentration in the rhizosphere was significantly higher compared to that determined in the non-rhizosphere. The calcium concentration was significantly higher in the rhizosphere at the surface level (R1-1, R2-1 and R3-1) compared to that observed in the non-rhizosphere and especially at deeper areas (5-10 cm). Although no significant difference was noted between rhizosphere and non-rhizosphere with respect to potassium (K) concentration, the trend on non-rhizosphere was slightly larger than that of rhizosphere. However, considering the different layers of depths, the concentration on the surfaces (0-5 cm) was significantly low compared to that of the deep zones (5-10 cm). The

phosphorus concentration was found to be significantly significant in the rhizosphere at the surface layer (R1-1, R2-1 and R3-1), while the lowest concentration was observed in the non-rhizosphere samples and especially in deep areas (NR1-2, NR2-2 and NR3-2).

1.3. Concentration of microelements

Microelements including iron (Fe), magnesium (Mg) and zinc (Zn) were also determined (Table 1). In the non-rhizosphere (NR1-1 and NR1-2), the Fe concentration was low, while in the remnants of the rhizosphere and non-rhizosphere samples it was significantly more considerable. Statistically no significant difference was noted between rhizosphere and non-rhizosphere. However, a considerable difference was observed when considering the variation in depth. The samples at the surface were significantly rich in iron unlike those at depth. The concentration of Mg measured in rhizosphere and non-rhizosphere showed no significant difference. However, the distribution of Zn in different experimental groups and different depths sampling was satisfactory and similar. Additionally, the lowest concentration was noted in some rhizosphere sampling areas such as R3-1 and R3-2.

Table 1: Identified bacterial OTU number, different microelements and others physicochemical properties of rhizosphere and non-rhizosphere at different depths layer

	OTUs	pH	ORP	Nitrate (mg/L)	NH3-N (mg/L)	C (%)
NR1-1	118861	6.59	56.0 ± 0.10	1.99 ±7.10	0.75 ±2.9	1.32 ±6.8
NR1-2	115117	6.64	23.6 ± 6.6	1.76 ±0.3	0.73 ±1.5	1.45 ±1.4
NR2-1	118129	6.71	17.5 ± 0.10	1.76 ±4.10	0.10 ±3.9	1.93 ±5.9
NR2-2	117628	6.82	-19.1 ± 6.6	1.61 ±4.10	0.51±0.2	1.80 ±2.1
NR3-1	119080	5.76	84.3 ± 3.3	1.88 ±2.10	0.35±5.7	1.12 ±5.9
NR3-2	117956	6.50	62.6 ± 6.6	1.73 ±2.10	0.31 ±5.9	1.23 ±7.4
R1-1	121902	6.24	17.0 ± 0.10	2.25 ±2.10	1.26±1.2	2.19 ±9.6
R1-2	121109	6.36	19.3 ±3.3	2.56 ±4.10	1.51 ±2.4	2.09 ±6.2
R2-1	127342	6.66	41.6 ±6.6	2.42 ±6.10	1.98 ±6.9	2.16 ±6.04
R2-2	122111	6.60	51.6 ±6.6	2.93 ±0.10	1.20 ±5.3	2.29 ±9.08
R3-1	123649	6.48	40.6 ±6.6	2.74 ±2.10	1.22 ±1.6	2.08 ±9.1
R3-2	122178	6.28	-101.3 ±3.3	2.92 ±8.10	1.22±1.6	2.40 ±7.9
	Ca (mg/kg)	**K (mg/kg)**	**P (mg/kg)**	**Fe (mg/kg)**	**Mg (mg/kg)**	**Zn (mg/kg)**
NR1-1	12.54±7.4	114.84 ±7.1	3.5628 ±0.5	7.87 ±3.6	3.38±2.4	0.22 ±0 .5
NR1-2	13.81±9.00	146.50 ±5.9	4.1681 ±6.2	9.01 ±6.5	3.69±8.3	0.24±1.6
NR2-1	14.72±7.5	161.23 ±4.2	5.0207 ±4.3	13.27 ±3.2	4.71±5.7	0.23 ±6.4
NR2-2	13.70±2.3	179.54 ±9.7	4.7709 ±6.3	12.28±9.3	4.66±6.6	0.24 ±7.9
NR3-1	12.85±8.8	126.44 ±1.9	4.99 ±8.05	13.68 ±7.1	4.48±3.3	0.24 ±5.2
NR3-2	12.03±6.7	153.09±4.10	3.02 ±1.6	17.68 ±1.2	5.43±9.4	0.23 ±5.9
R1-1	16.64±7.5	150.05 ±6.9	7.56 ±6.3	18.76 ±6.1	5.51±9.1	0.21 ±8.7
R1-2	15.63±6.5	165.15 ±1.2	6.67 ±1.07	15.75 ±7.3	4.58±3.3	0.22 ±3.1
R2-1	17.72±7.1	131.87 ±3.1	7.53 ±4.6	12.89 ±8.1	4.64±2.3	0.21 ±0.3
R2-2	16.85±7.6	156.46 ±6.7	8.25 ±1.4	19.08 ±3.8	5.79±6.7	0.23 ±9.2
R3-1	15.44±9.3	133.14 ±3.8	6.40 ±8.6	12.71 ±4.9	4.92±3.03	0.17 ±2 .5
R3-2	15.23±3.0	142.30 ±1. 9	5.33 ±1.5	14.16 ±5.9	5.02±4.4	0.14 ±3.7

Data are the mean of the three replications ± standard deviation and were compared using post-hoc Duncan's multiple range tests at $p<0.05$

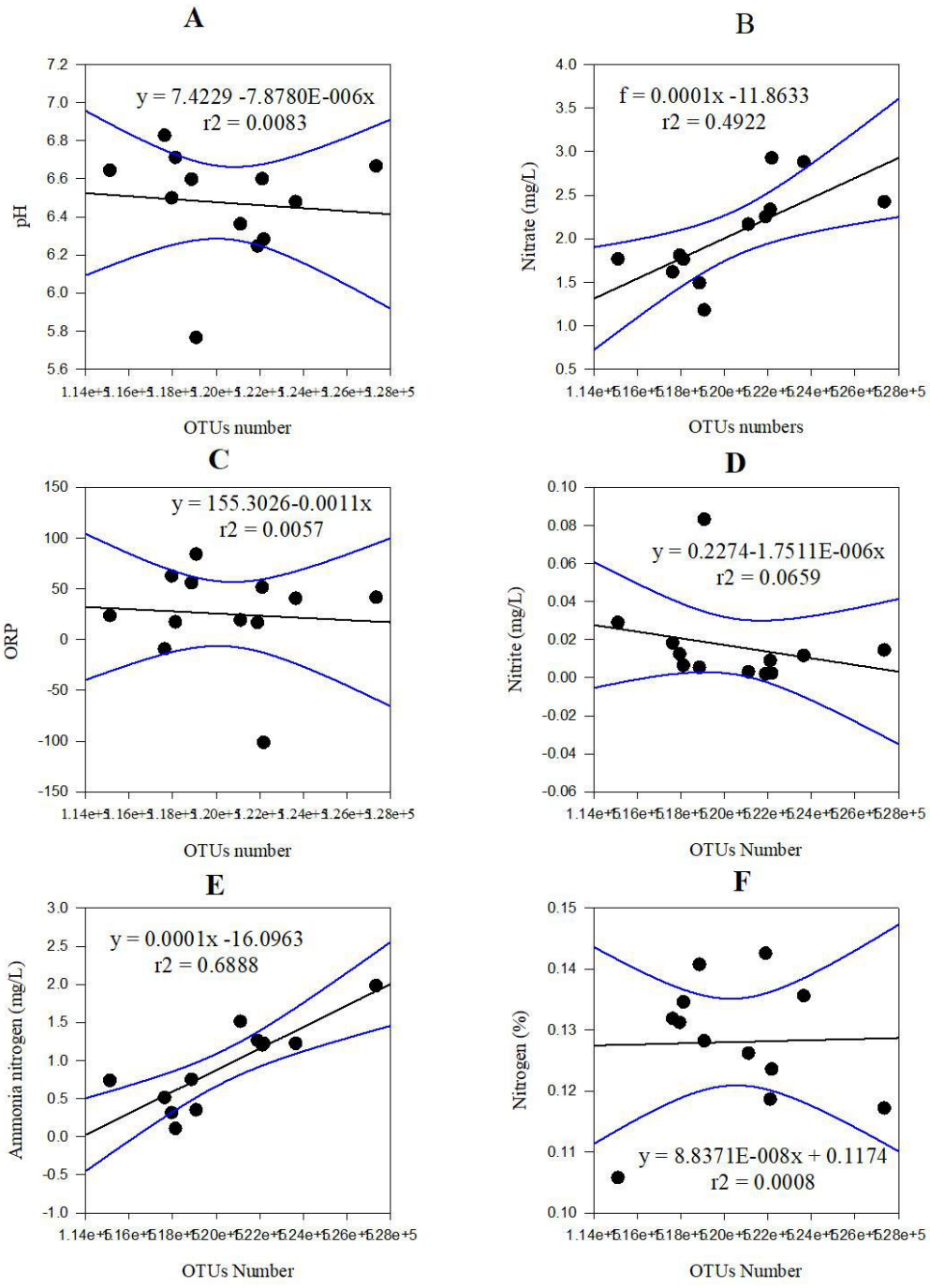

Fig.1: Correlation between pH (A), content of nitrate (B), nitrite (D), amoniacal nitrogen (E), nitrogen (F) and ORP (C) with identified OTU number.

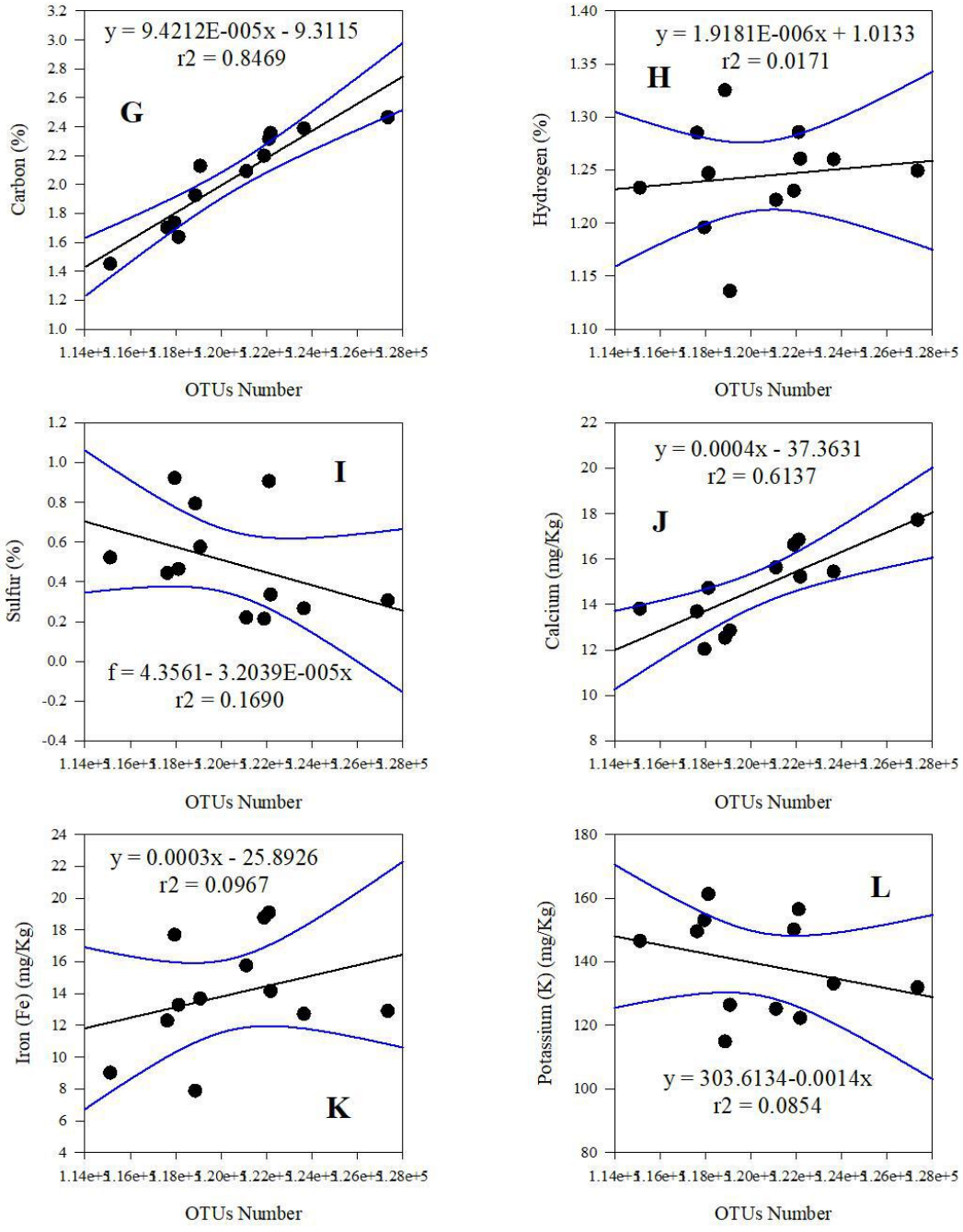

Fig.2: Correlation between carbon (G), hydrogen (H), sulfur (I), calcium (J), iron (K) and potassium (L) content with identified OTU number

2- Bacterial abundance in the rhizosphere and non-rhizosphere

Through 16S rRNA gene sequencing, 233978, 235757 and 237036 OTUs are identified in non-rhizosphere NR1, NR2 and NR3 respectively and 243011, 249453 and 245827 are identified in rhizospheres R1, R2 and R3 respectively (Table 1). The identified OTUs showed a slight difference between the NR and R samples. Taking into account the 'depth' factor, in the non-rhizosphere and rhizosphere samples, the more depth we gain, the number of identified OTUs decreased. The richness estimated by the Shannon and Chao 1 indices was significantly higher in the upper layer compared to that of the underlying samples (data not shown). This corroborates the fact that in the upper layer (0-5 cm), the relative abundance of microorganisms is more considerable compared to that of the sample taken in the deep zone, whether in the rhizosphere or in the non-rhizosphere.

3- Correlation between identified OTUs and environmental parameters

The correlation test was used for the possible impacts of different environmental parameters on the abundance of bacteria (Figure 1). It was found that the abundance of bacteria shows no correlation with pH (Figure 1A, r2 = 0.0083), neither with nitrate (Figure 1B, r2 = 0.4922), nor with nitrite (Figure 1C, r2 = 0.0659), neither with ORP (Figure 1D, r2 = 0.0057), nor with nitrogen content (Figure 1F, r2 = 0.0008). On the other hand, a positive correlation is observed between the abundance of bacteria with ammoniacal nitrogen (figure 1E, r2 = 0.6888).

The abundance of bacteria in the mangrove was high and positively correlated with soil carbon (Figure 2G, r2 = 0.8469), and moderately with soil calcium (Figure 2J, r2 = 0.6137). However, no correlation was observed between the identified OTUs and the hydrogen content (Figure 2H, r2 = 0.0171), or that of sulfur (Figure 2I, r2 = 0.1690), or with the iron content (Figure 2K, r2 = 0.0967) nor with that of potassium (Figure 2L, r2 = 0.0857).

Furthermore, the correlation test showed no relationship between the identified OTUs and the content of magnesium (Figure 3M, r2 = 0.1500), manganese (Figure 3N, r2 = 0.0047), phosphorus (Figure 3O, r2 = 0.3291) and zinc (Figure 3P, r2 = 0.2827).

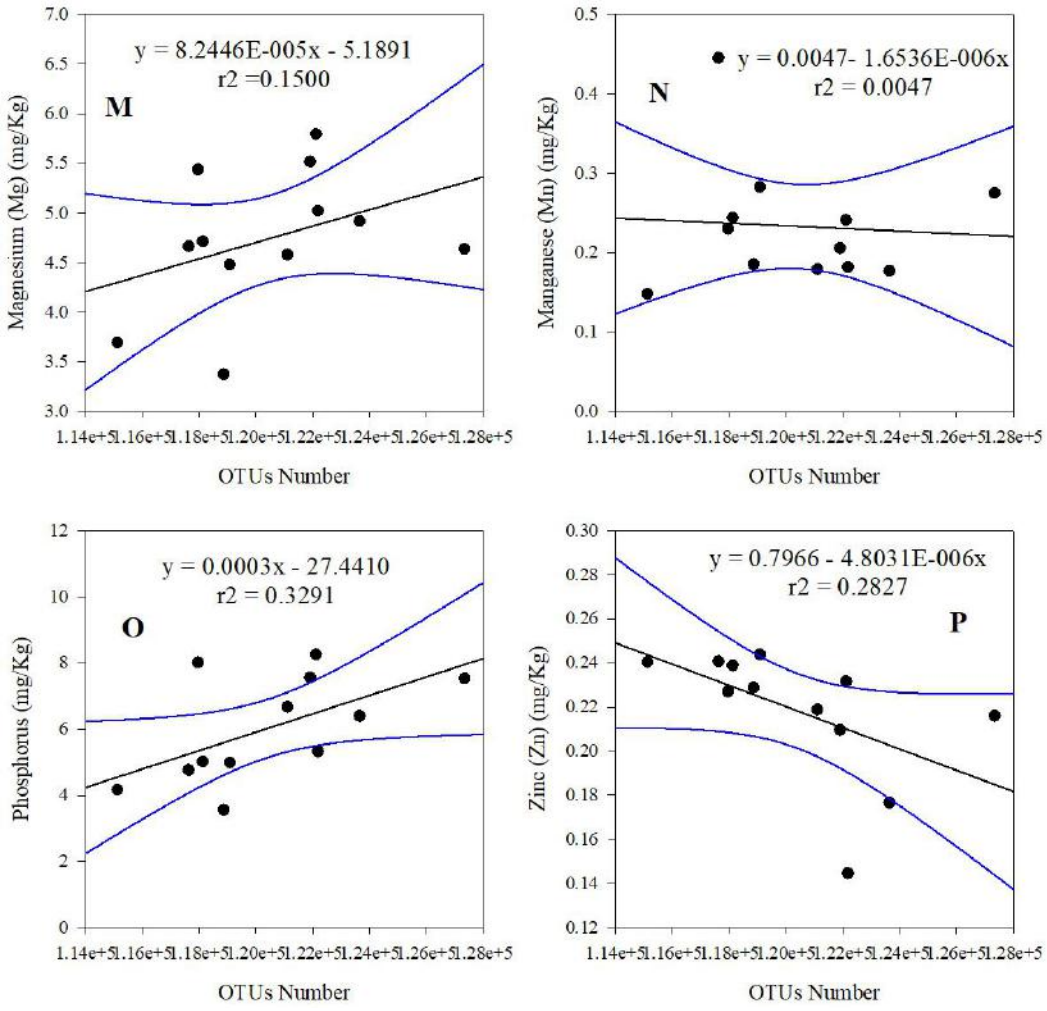

Fig.3: Correlation between magnesium (M), manganese (N), phosphorous (O) and zinc (P) content with the identified bacterial OTU

4-

Relative diversity and abundance based on the different taxa

Based on class level

Figure 4 shows the relative abundance of bacteria according to the different classes. Generally, microbial diversity in rhizosphere and non-rhizosphere was not felt. The distribution of taxonomic classes in the two experimental groups and that for all the different depth levels was similar. On the other hand, considering the relative abundance, the difference was much more evident between the experimental groups according to different depth levels. It is important to emphasize here that bacterial taxa less than or equal to 1% have been classified as others. The most presented bacteria belong to Gammaproteobacteria, Alphaproteobacteria, Desulfobulbia, Anaeroline and Desulfuromonadia with respectively, 14.18%, 12%, 13.4%, 12.57% and 10.81% in the rhizosphere samples against 13.28%, 11.86%, 11.63%, 9.18% and 9.10% in the non-rhizosphere. Moreover, taking into account the depth factor, the deeper we get, the more the bacterial abundance decreased. Indeed, in the upper layer (0-5 cm), the microbial abundance was significantly higher, while in the deeper zone (5-10 cm), only microbes with a concentration less than or equal to 1% increased. . This result corroborates the existing data according to which, in the ground, the bacteria are more important on the surface than in depth.

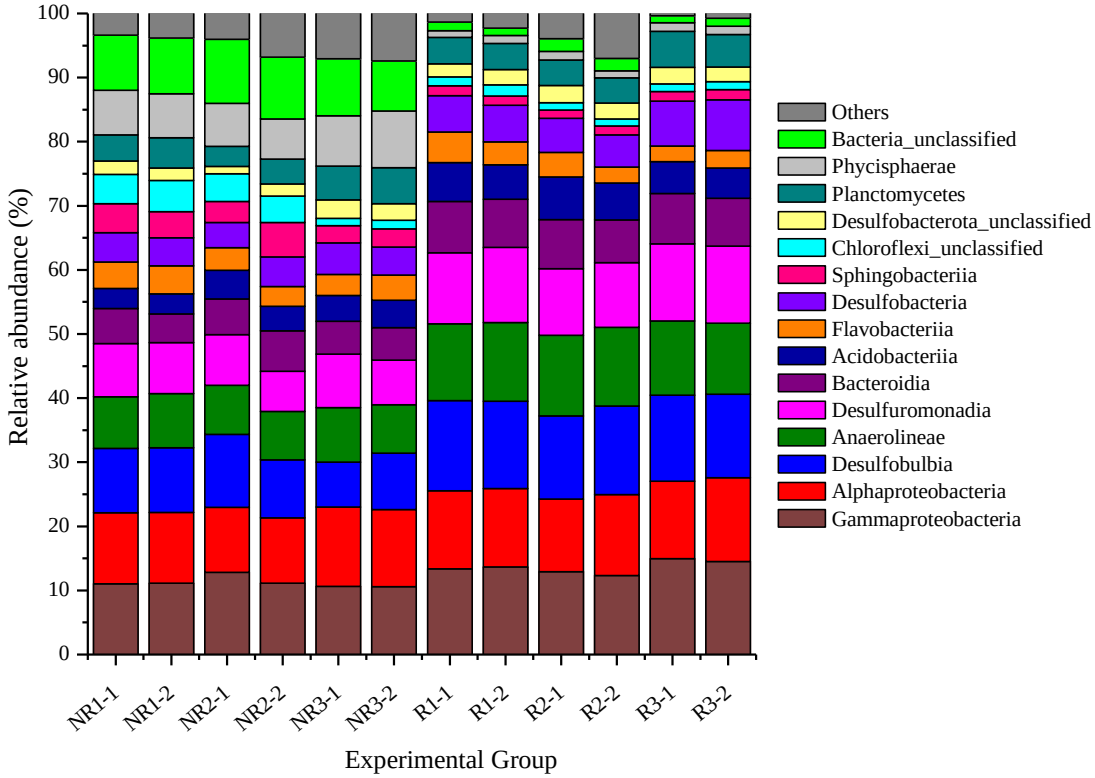

Fig.4: Relative bacterial abundance at the class level. The horizontal and vertical axis represent respectively the name of each sample and the abundance ratio in three repetitions. Each color corresponds to the name of the class and at the same time indicates the abundance of the different classes. NR = non-rhizosphere, R = rhizosphere

Based on genus level

The relative abundance of bacteria in the rhizosphere and non-rhizosphere of *R. mucronata* was further assessed at the genus level (Figure 5). The relative abundance of *Luteibacter*, *Alcanivorax*, *Pararhodobacter*, *Sphingobacterium* and *Pseudomonas* were significant in rhizosphere samples compared to non-rhizosphere with 10.66% # 4.12%, 16.20% # 6.31%, 9.55% # 3.39%, respectively, 9.50% # 5.48%, and 13.95% # 9.76%. In the non-rhizosphere samples, the genus *Dyella*, *Acidiphilium*, *Defluviimonas* and *Altererythrobacter* were identified as significantly abundant with 13.25%, 7.13%, 16.28% and 8.86% against 9.13%, 2.70%, 9.46% and 0.40% in those of the rhizosphere. Taking into account the depth factor, in the non-rhizosphere, the upper layer (0-5 cm) was more frequented by microbes than the deeper zone (5-10 cm). However, the situation in the rhizosphere showed no significant difference.

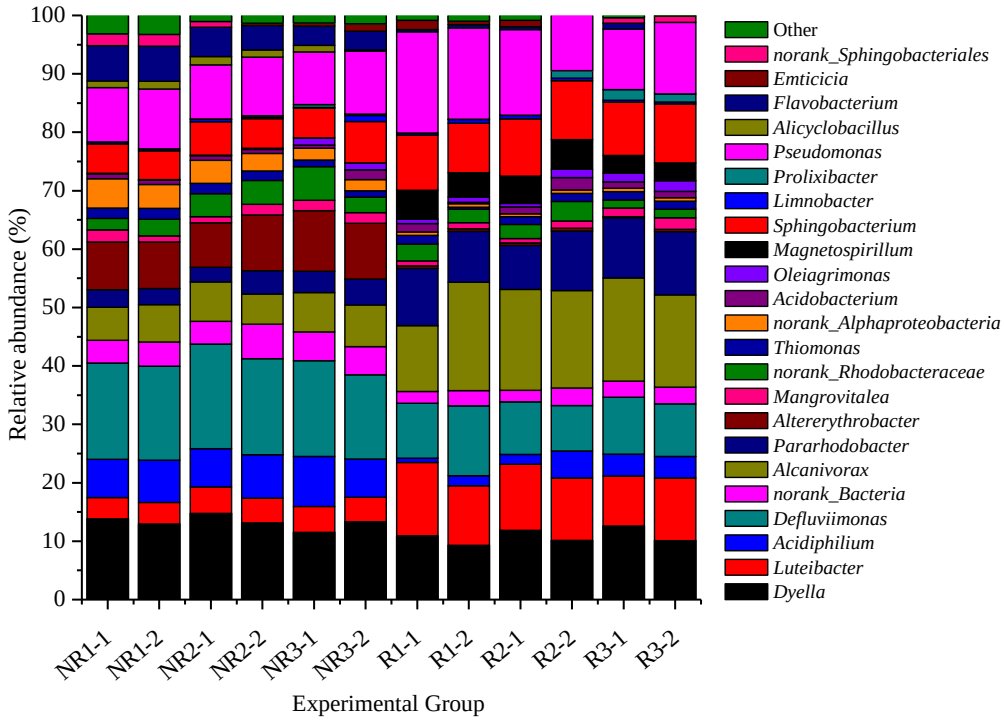

Fig.5: Relative bacterial abundance at the genus level. The horizontal and vertical axis represent respectively the name of each sample and the abundance ratio in three repetitions. Each color corresponds to the name of the class and at the same time indicates the abundance of the different genus. NR = non-rhizosphere, R = rhizosphere

IV. DISCUSSION

1- Modifications of the physical and chemical properties of the rhizosphere and the non-rhizosphere

It is evident that the availability of nutrients and the speciation of essential metals in plants are pH dependent (Schneider et al. 2013). Although no significant differences were noted when comparing pH in the rhizosphere and non-rhizosphere, root respiration and soil microorganisms are known to be a source of pH-lowering proton H+ production in the rhizospheres (Hinsinger et al. 2003). This could explain the slight variation in pH observed in the two experimental groups. The different forms of nitrogen determined vary from the rhizosphere to the non-rhizosphere and especially from one depth to another. This can be attributed to the process of net mineralization and sediment immobilization (Liu et al. 2020). Indeed, in the rhizosphere, the components of root exudates contribute not only to mineralization by enrichment in microorganisms, but also to immobilization via organic matter and by modifying redox conditions in the rhizosphere. Root activity through Root exudates of organic acids or root debris was the source of high organic carbon and nitrogen content in rhizosphere soil. High amounts of organic carbon in rhizosphere sediments may be due to high organic excretion and high levels of organic colloids.

The microelements in the rhizosphere can be influenced by their ionic species and their contents depending on the pH and the chemical composition of the root exudates (Chiu et al. 2002; Mishra et al. 2017). Fe and clay oxides can adsorb cationic heavy metals or form co-precipitates. In mangrove sediments, the potential for oxidation and reduction is highly variable (Wang et al. 2016). In the present study, it was observed that the oxidation occurs in the surface, while in the depths the reduction occurs. The trend of Zn availability in rhizosphere and non-rhizosphere was similar. The low concentration of Zn is explained by the fact that the oxides of Fe can specifically absorb it (Chiu et al. 2002). In the non-rhizosphere however, the low concentration of carbon molecules limited soluble complexes with Zn. This could explain the high concentration of Zn at the different depth layers.

2- Influence of physical and chemical properties on the bacterial community of the rhizosphere and non-rhizosphere

The dispersion of bacterial communities in the rhizosphere and non-rhizosphere was significantly different according to the different depth layers (Table 1).

This variation is mainly attributed to the different available nutrients, which in turn are conditioned by the physical and chemical properties of the sediments. Although these properties influence the bacterial community abundance of rhizosphere and non-rhizosphere sediments, their effects were variable with different depth variations. The abundance of the bacterial community on the superficial layers (0-5cm) was much greater. This would be related to the available nutrients, since the microbial richness in the vicinity of the rhizosphere is due to the excretions of root exudates (González-López and Ruano-Rosa 2020). However, on non-rhizosphere, nutrients would have their origin on the mineralization constituting an essential source of soil nutrients (Liu et al. 2020), or/and by the fact of tides and water runoff upstream of the mangroves. The correlation of the different factors and the abundance of bacteria in the different experimental groups (Figures 1. 2 and 3) would in fact be a consequence of the unequal distribution of resources. Numerous reports have shown that the correlation is always positive between the concentration of nutrients in the site and the abundance of microbes (Chen et al. 2016; Baumert et al. 2018). In general, given the rhizosphere effect exclusively defining the effectiveness of root exudates to promote multiplication, development and microbial growth in rhizosphere areas, studies unanimously tend to say that the microbial biomass is rather high. in the rhizosphere than in the non-rhizosphere (Gqozo et al. 2020; Li et al. 2016). Root exudates are an excellent source of nutrients for the development of microbes, which would be reasonable if the abundance of microbes is quite large in the rhizosphere, unlike non-rhizospheres. However, in our present study, although a slight abundance of bacteria was noted in the rhizosphere, no significant difference was observed, which contrasts with multiple published reports. Indeed if in general the root exudates increase the microbial biomass in the rhizosphere, this is not always the case in all circumstances. Studies by (DeAngelis et al. 2009; Mukerji et al. 2006) demonstrated that a selective effect on microorganisms can occur in areas of the rhizosphere, due to variations in root exudates depending on soil type, plant and microbial species. This can therefore lead to a large variation in the microbial biomass in the rhizosphere. Our study was conducted in mangroves which are quite particular plant species, not only by their distinctive abilities to grow in areas of high salinity and other waterlogging conditions, but also by their roots in structure and function unique. With the pneumatophore and stilt structure of mangrove roots, the excretion of root exudates and their mobility by seawater would be a consequence of the variation of nutrients on either side of the rhizospheres and non-rhizospheres. This could well lead to a variation in bacterial biomass between non-rhizosphere zones and rhizosphere zones.

V. CONCLUSION

In sum, through the present study, it was illustrated that the unequal distribution of nutrients in the rhizosphere and the non-rhizosphere of the mangrove species *Rhizophora mucronata* could be the consequences of mineralization, immobilization of nutrients in the soil and especially root exudation. The phylotypes identified in this study show that mangroves can serve as major discovery areas for microorganisms that can be used in various fields including bio-remediation of the polluted environment. Analysis of changes in the genomes of specific bacterial species would be one of the future works to illustrate the mechanism of their abilities to tolerate or degrade organic pollutants. Meta-genomics, meta-proteomics and meta-transcriptomics studies would also reveal the co-acclimatization and co-evolution of the bacterial community for better insight.

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